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USABILITY IMPROVEMENT FOR DATA INPUT INTO THE FATIGUE AVOIDANCE SCHEDULING TOOL (FAST)

James C. Miller

HUMAN EFFECTIVENESS DIRECTORATE
BIOSCIENCES AND PROTECTION DIVISION
FATIGUE COUNTERMEASURES BRANCH
8248 CHENNAULT PATH
BROOKS CITY-BASE TX 78235-5105

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//SIGNED//
JAMES C. MILLER, Ph.D.
Project Scientist

//SIGNED//
F. WESLEY BAUMGARDNER, Ph.D.
Deputy, Biosciences and Protection Division

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14. ABSTRACT

The Fatigue Avoidance Scheduling Tool (***FAST***™) was a Windows® program based upon the SAFTE applied fatigue model. ***FAST***™ allowed planners and schedulers to estimate the average effects of various schedules on human performance. It allowed work and sleep data entry in graphic, text and symbolic formats. We had set an objective to "Demonstrate fatigue management software interface improvements to achieve 20% increase in usability for field personnel." We hypothesized that data entry would be accomplished significantly faster by novice and expert users using the symbolic (grid) data input mode than using the graphic schedule input mode. The Grid input mode provided both a statistically and an operationally significant reduction in data input time, compared to the Graphic mode for both novice and expert users. We concluded that the Grid input mode offered a 40 to 45% reduction in *FAST*™ data input time, compared to the default Graphic input mode. This enhancement of data input speed was probably due to the need for fewer discrete input actions (keystroke and mouse). The Grid mode also appeared to be more intuitive for novice users than the Graphic input mode.

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PREFACE

This report covers the project period of 1 August to 30 September 2004. The work was performed under Job Order Number 7757P904. The project manager was Dr. James C. Miller, Senior Research Physiologist, Fatigue Countermeasures Branch, Biosciences and Protection Division, Air Force Research Laboratory.

SUMMARY

The Fatigue Avoidance Scheduling Tool (***FAST***™) was a Windows® program based upon the SAFTE applied fatigue model. ***FAST***™ allowed planners and schedulers to estimate the average effects of various schedules on human performance. It allowed work and sleep data entry in graphic, text and symbolic formats. We had set an objective to "Demonstrate fatigue management software interface improvements to achieve 20% increase in usability for field personnel." We hypothesized that data entry would be accomplished significantly faster by novice and expert users using the symbolic (grid) data input mode than using the graphic schedule input mode. The Grid input mode provided both a statistically and an operationally significant reduction in data input time, compared to the Graphic mode for both novice and expert users. We concluded that the Grid input mode offered a 40 to 45% reduction in *FAST*™ data input time, compared to the default Graphic input mode. This enhancement of data input speed was probably due to the need for fewer discrete input actions (keystroke and mouse). The Grid mode also appeared to be more intuitive for novice users than the Graphic input mode.

USABILITY IMPROVEMENT FOR DATA INPUT INTO THE FATIGUE AVOIDANCE SCHEDULING TOOL (*FAST*™)

INTRODUCTION

The Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) applied model integrated quantitative information about (1) circadian rhythms in metabolic rate, (2) cognitive performance recovery rates associated with sleep, and cognitive performance decay rates associated with wakefulness, and (3) cognitive performance effects associated with sleep inertia to produce a 3-process applied model of human cognitive effectiveness.

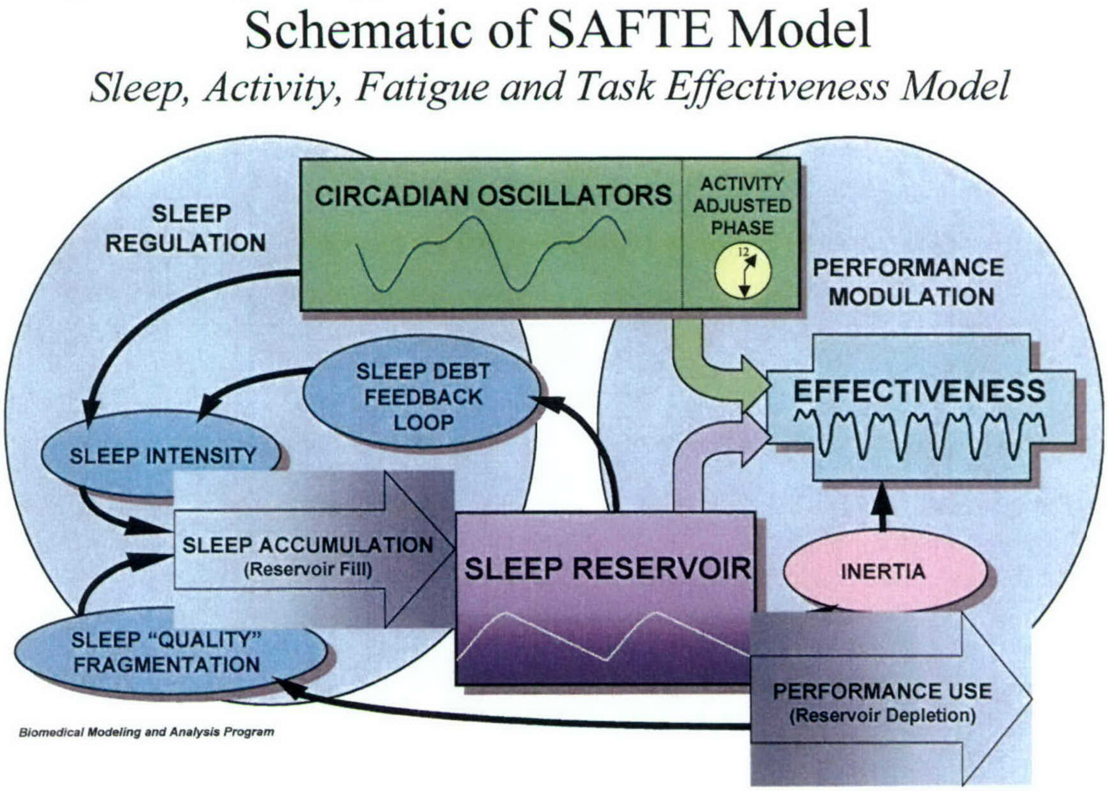
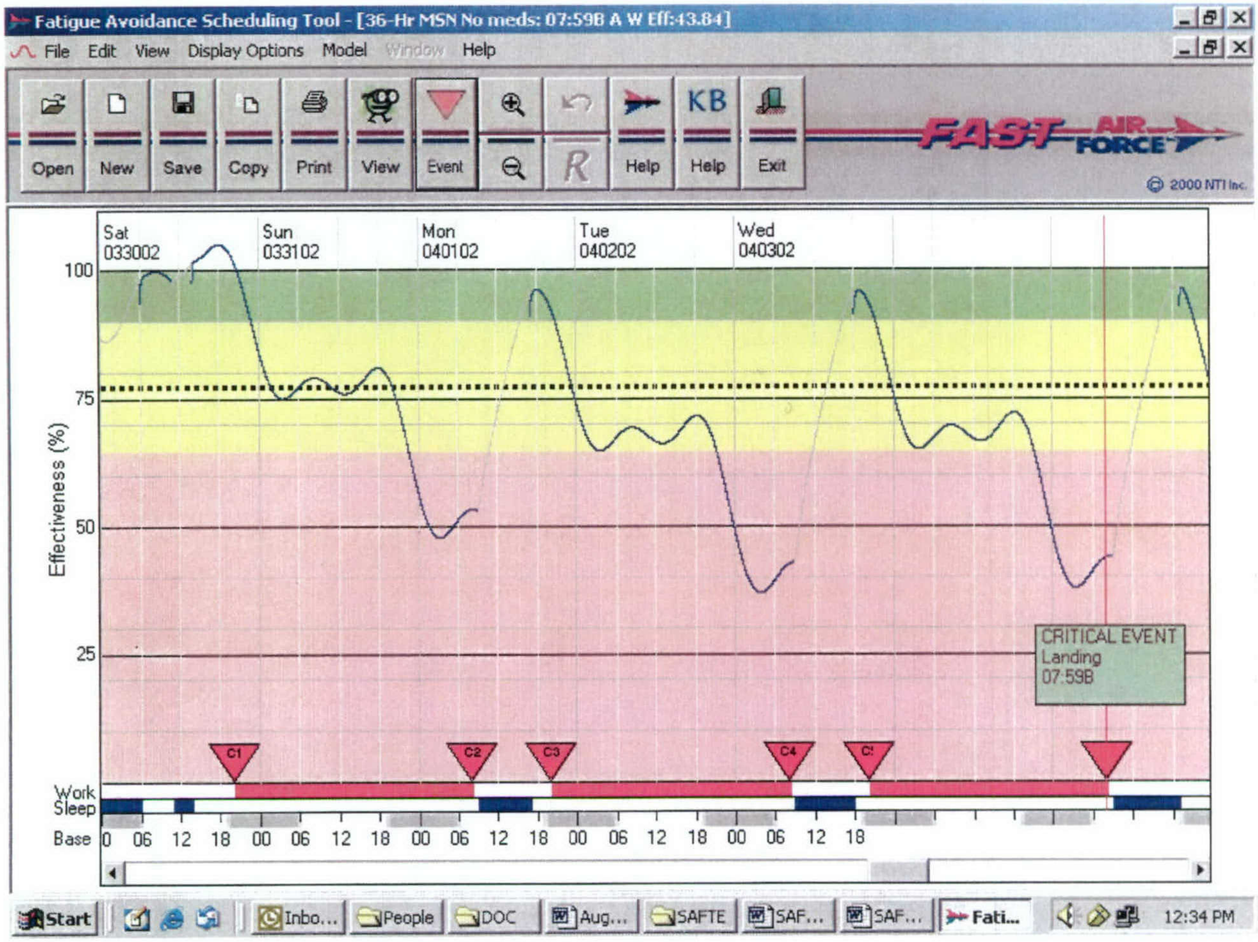


Figure 1

SAFTE had been validated against group mean data from a Canadian laboratory that were not used in the applied model's development (Hursh et al., 2004). Additional laboratory and field validation studies were underway and the applied model had begun the USAF Verification, Validation and Accreditation (VV&A) process.

The Fatigue Avoidance Scheduling Tool (***FAST***™) was a Windows® program based upon the SAFTE applied model. ***FAST***™, developed by NTI, Inc. (Dayton, Ohio) as an Air Force Small Business Innovation Research product, allowed planners and schedulers to estimate the average effects of various schedules on human performance. It allowed work and sleep data entry in graphic, text and symbolic formats. A work schedule comprised of three 36-hr missions each separated by 12 hours is shown as red bands on the time line across the bottom of the graphic presentation format in Figure 2. Average performance effectiveness for work periods could be extracted and printed as shown in the table below the figure.



36-Hr MSN No meds -- 03/30/2002

Awake			Work		
Start Day - Hr	Duration (Minutes)	Mean Effectiveness	Start Day - Hr	Duration (Minutes)	Mean Effectiveness
0 - 06:00	300	98.97	0 - 20:00	1079	81.14
0 - 14:00	2580	76.42	1 - 14:00	1080	63.97
2 - 17:00	2400	64.78	2 - 20:00	1079	71.23
4 - 18:00	2340	64.58	3 - 14:00	1080	54.51
6 - 19:00	1741	72.23	4 - 20:00	1079	72.00
			5 - 14:00	1080	54.92

Figure 2. Sample ***FAST***™ display. The triangles represent waypoint changes that control the amount of light available at awakening and during various phases of the circadian rhythm. The table shows the mission split into two work intervals, first half and second half.

- Sleep periods are shown as blue bands across the time line, below the red bands.
- The vertical axis of the diagram represents composite human performance on a number of associated cognitive tasks. The axis is scaled from zero to 100%. The

oscillating line in the diagram represents expected group average performance on these tasks as determined by time of day, biological rhythms, time spent awake, and amount of sleep. We would expect the predicted performance of half of the people in a group to fall below this line.

- The green area on the chart ends at the time for normal sleep, ~90% effectiveness.
- The yellow indicates caution.
- The area from the dotted line to the red area represents performance level during the nadir and during a 2nd day without sleep.
- The red area represents performance effectiveness after 2 days and a night of sleep deprivation.

The expected level of performance effectiveness was based upon the detailed analysis of data from participants engaged in the performance of cognitive tasks during several sleep deprivation studies conducted by the Army, Air Force and Canadian researchers. The algorithm that created the predictions had been under development for two decades and represented the most advanced information available.

DEFENSE TECHNOLOGY OBJECTIVE

The data reported here supported a Fiscal Year 2004 Defense Technology Objective milestone, "Demonstrate fatigue management software interface improvements to achieve 20% increase in usability for field personnel."[1]

DATA INPUT OPTIONS

Sleep and work intervals could be edited (1) on a graphic schedule display by using a cursor in conjunction with certain keyboard commands, (2) by typing alphanumerics into a table, or (3) in a symbolic format in a grid. Options 1 and 3 were compared here.

HYPOTHESES

- Data entry will be accomplished significantly faster by some members of a potential user group who use the symbolic data input mode (option 3, above) than by other members of the group who use the graphic schedule input mode (option 1, above).
- Data entry will be accomplished significantly faster by expert users using the symbolic data input mode (option 3, above) than by the same users using the graphic schedule input mode (option 1, above).

[1] JWSTP DTO JE.35, Fatigue Management Capability for Sustained Readiness and Performance

METHODS

NOVICES

This brief experiment was based upon a 2-sample, independent groups design. The two samples (Graphic, Symbolic) consisted of 11 participants, each. Two-tailed statistical significance was accepted at the 95% level of confidence. Test power was 60% for an effect size of one standard deviation.

The participants were attending a 2-day Military Aviation Fatigue Countermeasures course presented several times per year by Drs. John A. Caldwell and J. Lynn Caldwell and the investigator at Brooks City-Base, San Antonio, Texas. The course was "aimed at military personnel with a basic understanding of the problem of fatigue in operational environments, and/or those who are anticipating new duty assignments in which they will bear some responsibility for the alertness management of aviators, maintenance crews, controllers, or other personnel." The course outlined "the dangers of fatigue in military aviation and related operations, the basic mechanisms underlying fatigue, the most common causes of overly-tired personnel, and the best techniques of optimizing alertness in military environments." Participants received "instruction on the effective design of crew work/rest schedules and the use of a computerized scheduling tool [***FAST***™]."

Usability testing occurred on the afternoon of the second day of the Fatigue Countermeasures Course, following 2 hours of afternoon instruction on the use of ***FAST***™. Both the instruction and the testing occurred on a homogeneous set of personal computers in a computer classroom at the USAF School of Aerospace Medicine (Building 775, Brooks City-Base).

Sleep and work intervals could be edited on a default graphic schedule display by using a cursor in conjunction with certain keyboard commands. A single mouse click positioned the cursor at the mouse pointer location. Pressing and holding the left mouse button allowed the user to drag the cursor. A list of commands was made available in hard copy to users in the Graphic group (Appendix A). Visual feedback was provided by ***FAST***™ to the users as shown in Figures 3 and 4.

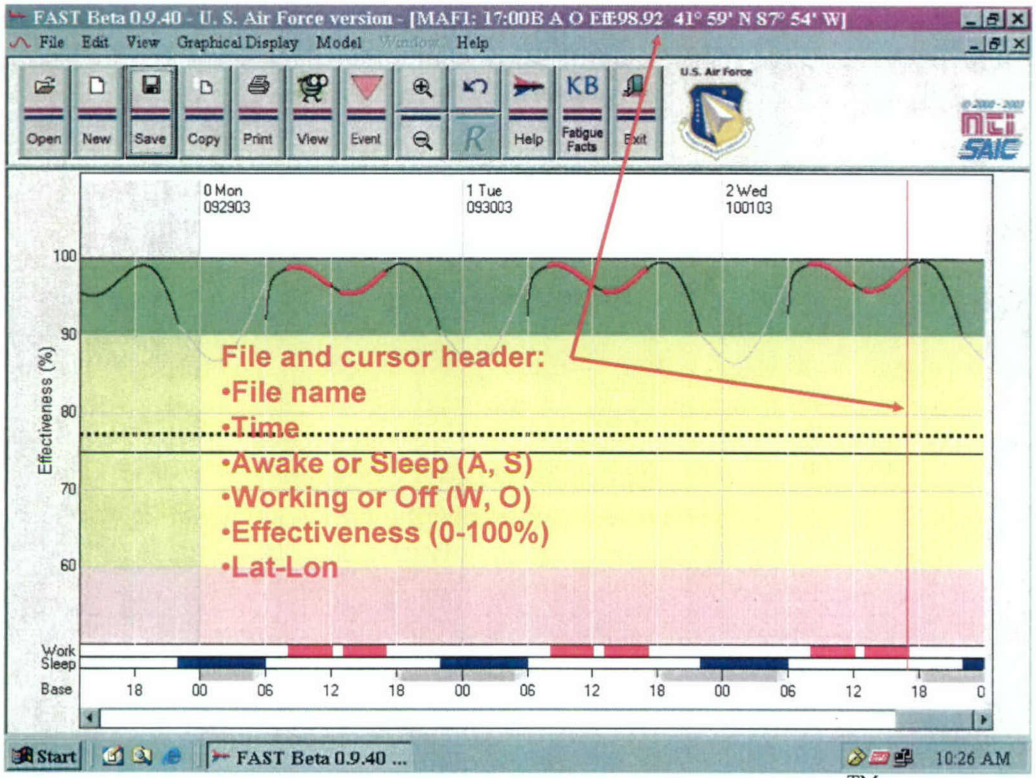


Figure 3. Visual feedback in the Graphic display mode of ***FAST***™ concerning the file name and cursor location.

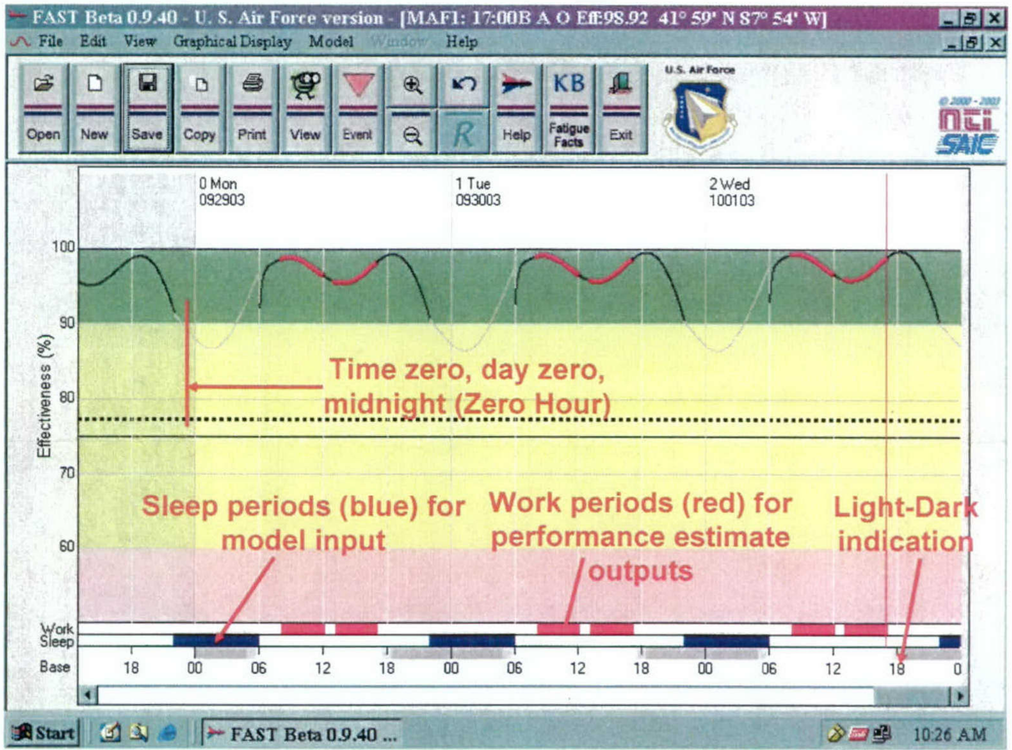


Figure 4. Visual feedback in the Graphic display mode of ***FAST***™ concerning sleep and work periods.

Sleep and work intervals could also be edited in a symbolic format by selecting *Edit Sleep Schedule Grid* from the Edit menu. A matrix, or grid, was displayed with hours labeled along the top and days labeled along the left margin, defining the time in the schedule in 15 minute intervals (Figure 5). The instructions for using the grid mode were:

- Press the left mouse button and drag the mouse across the grid to highlight an interval. The position of the mouse is shown alphanumerically at the top of the grid.
- Release the button and select the type of interval: Sleep, Work, Clear, or Cancel.
- Rows of the grid can be copied and pasted elsewhere in the grid using standard MS Windows commands. Highlight rows of the grid by dragging the mouse down the left margin; release the mouse button and select copy or paste.
- When done editing the schedule, select OK, and the new intervals are entered into the schedule.
- Any intervals that need to be adjusted to finer detail than 15 minutes may be edited by Edit Sleep and Work Intervals methods or directly on the graphical screen.
- The grid may be copied to the clipboard using the Copy button and pasted into a graphics program as an illustration of the schedule.

This list of commands was made available in hard copy to users in the Graphic group (Appendix B). Visual feedback was provided by ***FAST***™ to the users as shown in Figure 5.

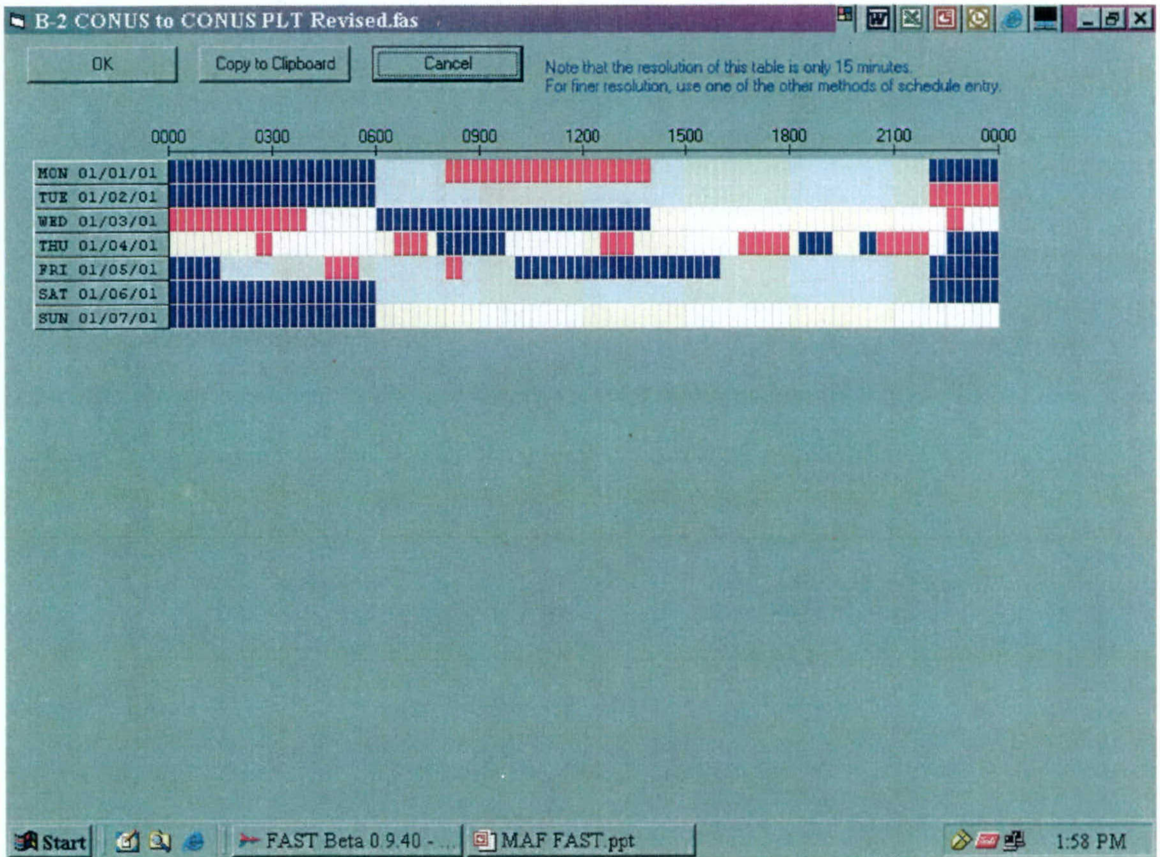


Figure 5. Visual feedback in the Grid display mode of ***FAST***™ concerning sleep and work periods.

Procedures
Instruction included (1) a brief introduction to the SAFTE model, (2) a hands-off, audio-visual presentation of the ***FAST***™ screens and menus and (3) a hands-on entry of data for a sample problem. All hands-on data entry for item 3 was conducted with the Graphic input mode. The operation of the Grid mode was then demonstrated hands-on, briefly.

For usability testing, assignments to the Graphic and Grid groups were made alternately across the rows of participants as they sat in the computer classroom. The test data (Appendix C) were distributed and reviewed and questions were answered.

All participants closed their existing ***FAST***™ file and opened a new file. All defaults for Schedule Properties were accepted, with the exception of specifying a schedule duration of 35 days. The default Graphic display window was maximized. All participants began data entry from this point in the software and at the same time. Times to complete data entry were recorded manually by each participant and then by the investigator. This was the only datum collected from an individual participant.

EXPERTS
This brief experiment was based upon a repeated measures design. The sample consisted of 5 participants. Two-tailed statistical significance was accepted at the 95% level of confidence. Test power was 47% for an effect size of one standard deviation and an expected within-subject correlation across conditions of $r = 0.30$. The same data that were entered by Novice users were also entered by the Expert users. Three experts used the Grid mode first, and the other two experts used the Graphic mode first.

MODE ACTION COMPARISON
The actions required (keystrokes and mouse click) to input the first night shift in each mode are described here. It is assumed that a new *FAST*™ file has been opened and is ready for data input. For the default Graphic mode:

1. Use a combination of a mouse click and cursor key strokes, amplified by the Control key as needed, to place the *FAST*™ cursor on the correct start time.
2. Press the W key to indicate the start of the work period.
3. Use a combination of a mouse click and cursor key strokes, amplified by the Control key as needed, to place the *FAST*™ cursor on the correct end time.
4. Press the Shift and W keys to indicate the end of the work period.

For the Grid mode:

1. Place the mouse cursor on the start time and press and hold the left mouse button.
2. Drag the mouse cursor to the end time and release the left mouse button (a new interaction window appears automatically).
3. Place the mouse cursor on the "work" radio button and click the left mouse button.

Four discrete actions were required in the Graphic mode to enter this one datum. Three actions were required in the Grid mode, and it may be argued that the first two actions constituted one discrete action.

For this study, we used *FAST*™ beta version 1.0.13 with the following parameter values:

Model Parameters	**Values**
24-hr rhythm acrophase	18
12-hr rhythm phase offset	3
Relative amplitude of 12-hr rhythm	0.5
Sleep propensity mesor	0
Sleep propensity amplitude	0.55
Maximum sleep accumulation per minute	3.4
Performance rhythm amplitude (fixed %)	7
Performance rhythm amplitude (variable %)	5
Reservoir capacity	2880
Feedback amplitude	0.0031200
Sleep inertia time constant	0.04
Maximum inertia following awakening (%)	5
Performance use rate	0.5
Slow recovery	
K1	0.22
K2	0.5
K3	0.0015
Sleep environment	
Excellent	1
Moderate	0.83
Poor	0.5

RESULTS

NOVICES

Most of the participants were USAF active duty or civilians and included a cross section of expected FAST users: aerospace physiologists (including two from the Canadian Air Force), flight surgeons, safety officers (including one from the FAA and one from Army Aviation), and scientists.

There was a statistically significant difference between the two Groups' input times (Table 1 and Appendix E-1), according to the results of a 2-tailed, independent-groups t test ($p = 0.014$). The Grid mode input time for the 5-week shiftwork schedule was 61% of the input time for the same data entered using the Graphic input mode.

TABLE 1. Data entry times in minutes for novice users in the Graphic and Grid groups. One participant in the Graphic group gave up after several attempts.

Group:	Graphic	Grid
Minimum	7	3
Maximum	21	16
Mean	12.1	7.4
Std Dev	4.1	3.9
n	10	11

EXPERTS

There was a statistically significant difference between the input times for the two modes (Table 2 and Appendix F-1), according to the results of a 2-tailed, repeated-measures t test ($p = 0.014$). The Grid mode input time for the 5-week shiftwork schedule was 55% of the input time for the same data entered using the Graphic input mode.

TABLE 2. Data entry times in minutes for five expert users

Mode:	Graphic	Grid
Minimum	5	3
Maximum	10	7
Mean	8.4	4.6
Std Dev	2.3	1.5

DISCUSSION

Both hypotheses were supported. The Grid input mode provided both a statistically and an operationally significant reduction in data input time, compared to the Graphic mode. For novice users, the Grid group input time for the 5-week shiftwork schedule was 61% of the input time for the Graphic group. For five expert users, the Grid mode input time for the 5-week shiftwork schedule was 55% of the input time for the same data entered using the Graphic input mode.

A former instructor of *FAST*™ classes provided by AFRL and USAFSAM commented, "When I started teaching the *FAST*™ class with the scheduling grid, class time went down considerably -- from 3 hrs to 1.5-2 hrs. I still used the same schedule [for data input], but there were far fewer questions during the "do it yourself" portion of the class because everyone used the schedule grid. There may have been some extraneous variables contributing to the decrease in time, but I think it's mostly due to the intuitiveness of the scheduling grid." (Capt D.R. Wheeler, personal communication, 2004).

The Grid input mode offered a 40 to 45% reduction in *FAST*™ data input time, compared to the default Graphic input mode. This enhancement of data input speed was probably due to the need for fewer discrete input actions (keystroke and mouse). The Grid mode also appeared to be more intuitive for novice users than the Graphic input mode.

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Eddy DR, Hursh SR (2001). *Fatigue Avoidance Scheduling Tool (FAST)*. AFRL-HE-BR-TR-2001-0140, SBIR Phase I Final Report, Human Effectiveness Directorate Biodynamics and Protection Division, Flight Motion Effects Branch, Brooks AFB TX 78235-5105.

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APPENDIX A
Mouse and Keyboard Commands for Graphic Mode Data Entry

Sleep and work intervals may be edited on the default graphic schedule display by using the cursor in conjunction with certain keyboard commands. A single mouse click positions the cursor at the mouse pointer location. Pressing and holding the left mouse button allows you to drag the cursor. The keyboard commands are as follows:

- **Navigation:**

Move cursor one minute left (earlier)	Left arrow
Move cursor one minute right (later)	Right arrow
Move cursor 30 minutes left (earlier)	CTRL + Left arrow
Move cursor 30 minutes right (later)	CTRL + Right arrow
Move cursor to the next event	E
Move cursor to the previous event	Shift+E
Move cursor to start of next hour	H [Hour]
Move cursor to start of previous hour	Shift+H
Move start of window to current cursor location	J [Jump]
Move cursor to first minute of day -3	HOME
Move cursor to first minute of last screen (page)	END
Open next page as set by the window size	Page Down
Open prior page (if any)	Page Up
Switch labels on time axis	ALT+L
Toggle between graphical and tabular data display	ALT+Z
Recalculate model and refresh display (when indicator flashing)	R
Cancel any ongoing keyboard operation and hide any information panels that may be displayed	ESC

- **Schedule Editing:**

Start Sleep interval	S [Sleep]
End Sleep interval	Shift+S
Start Awake interval	A [Awake]
End Awake interval	Shift+A
Start Work interval	W [Work]
End Work interval	Shift+W
Start Off Work interval	O [Off]
End Off Work interval	Shift+O
Duplicate Day 0 sleep and work pattern for remaining days	CTRL+D

- **Event Editing:**

Insert an Event at the current cursor position	CTRL+E
Delete event at cursor position	ALT+E
Delete all events	CTRL+ALT+E

- **Define Statistics Interval:**

Start interval (blue dotted line displayed)	I [Interval]
End interval (second line + stat box displayed)	Shift+I

APPENDIX B
Mouse Commands for Grid Mode Data Entry

A matrix, or grid, is displayed with hours labeled along the top and days labeled along the left margin, defining the time in the schedule in 15 minute intervals. The instructions for using the grid mode are:

- Select *Edit Sleep Schedule Grid* from the Edit menu.
- Press the left mouse button and drag the mouse across the grid to highlight an interval. The position of the mouse is shown alphanumerically at the top of the grid.
- Release the button and select the type of interval: Sleep, Work, Clear, or Cancel.
- Rows of the grid can be copied and pasted elsewhere in the grid. Highlight rows of the grid by dragging the mouse down the left margin; release the mouse button and select copy or paste.
- When done editing the schedule, select OK, and the new intervals are entered into the schedule.
- Any intervals that need to be adjusted to finer detail than 15 minutes may be edited by Edit Sleep and Work Intervals methods or directly on the graphical screen.
- The grid may be copied to the clipboard using the Copy button and pasted into a graphics program as an illustration of the schedule.

APPENDIX C
Input Usability Data for Novices

Please input the following actual shiftwork schedule for **Team A** (Table 1) using your assigned method: either (1) the ***FAST***™ **graphic** input screen (the default ***FAST***™ view) or (2) the ***FAST***™ **grid** screen (entered from the Edit menu). Please measure and record, to the **nearest minute**, the amount of time required for you to enter these data in your assigned input mode. Record your data here…

Assigned input mode (circle one): Graphic Grid

Time required for schedule input: _______ (minutes)

Report your input mode and time to Dr. Miller and keep this test sheet.

Schedule

This is a 4-team, 28-day cycle with a 5th team and 5th week tacked on to allow for admin and training (Table 1). The lag time across teams is 7 days. The use of a 5-team schedule is best described by P Westfall-Lake & GN McBride in *Shiftwork, Safety and Performance* (Lewis Publishers, 1998). In fact, three other versions of this very schedule are shown on pages 88-89 of that book.

Table 1. 5-team schedule. D [(highlighted in yellow) = 8-hour day shift, 0800-1600; else D = 12-h day shift and N = 12-h night shift with change times of 0530 and 1730.

Team	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We
A	**--**	**N**	**N**	**--**	**--**	**D**	**D**	**D**	**--**	**--**	**N**	**N**	**--**	**--**	**--**	**D**	**D**
B	D	D	D	D	D	--	--	--	N	N	--	--	D	D	D	--	--
C	N	--	--	D	D	--	--	D	D	D	D	D	--	--	--	N	N
D	--	D	D	--	--	N	N	N	--	--	D	D	--	--	D	D	D
E	D	--	--	N	N	--	--	--	D	D	--	--	N	N	N	--	--

(Table 1, continued)

Team	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A	**--**	**--**	**N**	**N**	**N**	**--**	**--**	**D**	**D**	**--**	**--**	**D**	**D**	**D**	**D**	**D**	**--**	**--**
B	N	N	--	--	--	D	D	--	--	N	N	N	--	--	D	D	--	--
C	--	--	D	D	D	--	--	N	N	--	--	--	D	D	--	--	N	N
D	D	D	--	--	--	N	N	--	--	D	D	D	--	--	N	N	--	--
E	D	D	--	--	D	D	D	D	D	--	--	--	N	N	--	--	D	D

I modeled the work schedule and the expected sleep pattern associated with FAST® (Figure 1). Critical fatigue points for safety-sensitive jobs (below 90% cognitive effectiveness) are predicted to occur during <u>all</u> 12-h N <u>and</u> D shifts! Additional critical fatigue points (below 78% cognitive effectiveness) occur in the second halves of <u>all</u> night shifts.

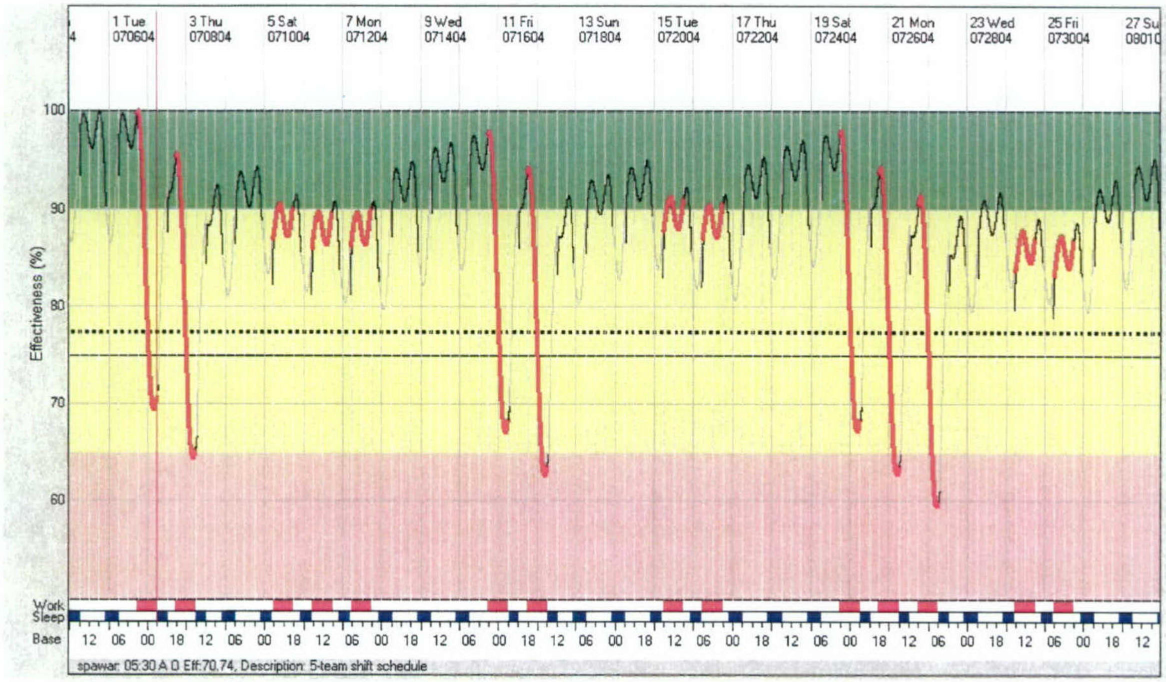

Figure 1. First 4 weeks of 5-team schedule with 0530-1730h shift change times. Bold red = work periods. Green-yellow boundary = 90% cognitive effectiveness. Yellow-red boundary = 65% cognitive effectiveness.

I was a bit surprised by the amount of work time spent below 90% cognitive effectiveness during day shifts in this schedule. I noted that, after the last two night shifts before the added week of "normal" 8-h days, about five days of recovery are needed before operators can work an entire day shift above 90% cognitive effectiveness.

What simple scheduling change will help elevate predicted effectiveness during work hours?

APPENDIX D
Input Usability Data for Experts

Please input the following actual shiftwork schedule for **Team A** (Table 1) using two methods: the ***FAST***™ **graphic** input screen (the default ***FAST***™ view) and the ***FAST***™ **grid** screen (entered from the Edit menu). Please measure and record, to the **nearest minute**, the amount of time required for you to enter these data in each input mode. Report your times to Dr. Miller.

Schedule

This is a 4-team, 28-day cycle with a 5th team and 5th week tacked on to allow for admin and training (Table 1). The lag time across teams is 7 days.

Table 1. 5-team schedule. D [(highlighted in yellow) = 8-hour day shift, 0800-1600; else D = 12-h day shift and N = 12-h night shift with change times of 0530 and 1730.

Team	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We
A	**--**	**N**	**N**	**--**	**--**	**D**	**D**	**D**	**--**	**--**	**N**	**N**	**--**	**--**	**--**	**D**	**D**
B	D	D	D	D	D	--	--	--	N	N	--	--	D	D	D	--	--
C	N	--	--	D	D	--	--	D	D	D	D	D	--	--	--	N	N
D	--	D	D	--	--	N	N	N	--	--	D	D	--	--	D	D	D
E	D	--	--	N	N	--	--	--	D	D	--	--	N	N	N	--	--

(Table 1, continued)

Team	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A	**--**	**--**	**N**	**N**	**N**	**--**	**--**	**D**	**D**	**--**	**--**	**D**	**D**	**D**	**D**	**D**	**--**	**--**
B	N	N	--	--	--	D	D	--	--	N	N	N	--	--	D	D	--	--
C	--	--	D	D	D	--	--	N	N	--	--	--	D	D	--	--	N	N
D	D	D	--	--	--	N	N	--	--	D	D	D	--	--	N	N	--	--
E	D	D	--	--	D	D	D	D	D	--	--	--	N	N	--	--	D	D

APPENDIX E
Data for Novice Users

TABLE E-1. Raw data entry times in minutes for novice users in the Graphic and Grid groups. One participant in the Graphic group gave up after several attempts.

Group	Graphic	Grid
	7	5
	12	5
	12	4
	12	3
	9	8
	9	8
	17	6
	21	9
	12	5
	10	16
		12
Minimum	*7*	*3*
Maximum	*21*	*16*
Mean	*12.1*	*7.4*
Std Dev	*4.1*	*3.9*
n	*10*	*11*
Independent t		*p = 0.014*
%		*60.9%*

APPENDIX F
Data for Expert Users

TABLE F-1. Raw data entry times in minutes for expert users.

	Graphic (in min)	Grid (in minutes)
	10	4
	7	5
	10	7
	10	4
	5	3
Minimum	*5*	*3*
Maximum	*10*	*7*
Mean	*8.4*	*4.6*
Std Dev	*2.3*	*1.5*
n	*5*	*5*
Paired t		*p = 0.014*
%		*54.8%*